The Vowel Space of Persian Nasalized Vowels

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Abstract
This paper is an acoustic analysis of Persian nasalized vowels which aims to develop an acoustic vowel space of these vowels compared to that of oral vowels (the vowel space provides a graphical method for showing where a speech sound, such as a vowel, is located in both "acoustic" and "articulatory" space. The illustration shows an acoustic vowel space based on the first two formants for vowels. The vertical axis represents the frequency of the first formant (F1) and the horizontal axis shows the frequency gap between the first two formants (F2-F1) (Giacomino, 2012). In this regard, such a survey is investigating the effect of nasalization on the first and second formants of Persian vowels as well as the effect of this factor on their F1span and F2span. In addition, this article studies the effect of gender on the first two formants of oral and nasalized vowels.

In order to reach the purposes of this survey, the speech of a total of ten Persian speakers, including five women and five men were recorded. All of the speakers were between the ages of 25 and 35. A list of forty-eight words (the words were embedded in a common carrier sentence) was presented to the speakers and their utterances of the words were recorded with a Huawei G750-U10 sound recorder. The words the participants had to pronounce were two to three syllabic nouns and adjectives. The findings of this paper are based on the pronunciation of six vowels, i.e., /i/, /e/, /a/, /ɑ/, /o/ and /u/ found in the unstressed syllable of these words. Some of these unstressed syllables contained a consonant-vowel-consonant phoneme structure (i.e. /CVC/) and some others contained a nasal-vowel-nasal one (i.e. /NVN/) in order to examine oral and nasal vowels, respectively.

Each word was uttered five times by each speaker, so each one provided 240 tokens. Collectively, 2400 tokens were provided by the participants. The recorded words were converted to .WAV files and analyzed acoustically with the free program, Praat (an online open source software designed for acoustic phonetic

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analyses). The data taken were the first two vowel formants, i.e., F1 and F2. For the purposes of this study the central part of each vowel, which reaches a practically steady state, was measured. Averages were taken for each value for each speaker and then calculated for the entire group. It should be mentioned that mahalanobis distance criterion was used to remove outlier data. Generally, this criterion is used when the data are two-dimensional.

The data, when so analyzed statistically, reveal that nasalization significantly affects all vowels' first and second formants. In fact, the F1 frequency of the nasalized vowels, except for the vowel /a/, is more than that of oral vowels. In comparison with the oral vowel /a/, the F1 frequency of its nasalized counterpart is less. Moreover, the F2 frequency of the nasalized vowels is more than that of oral vowels.

It is also found that nasalization has no significant effect on vowels' F1span and F2span.

The data show that, gender significantly affects the frequency of the first two formants in both oral and nasalized vowels, except for the vowel /u/. The effects may be indicated as follows.

a. In nasalized vowels as well as oral ones, the F1 frequency of the vowels /o/, /ɑ/, /e/ and /a/ for female speakers is more than that of these vowels for male ones. Additionally, the F1 frequency of the nasalized vowel /i/ for females is less than that of this vowel for males, but conversely, the F1 frequency of the oral one for females is more than that of this vowel for males.

b. In both nasalized and oral vowels, the F2 frequency of the vowels /ɑ/, /i/, /e/ and /a/ for female speakers is more than that of these vowels for male ones. Furthermore, the F2 frequency of the nasalized vowel /o/ for females is less than that of this vowel for males but conversely, the F2 frequency of the oral one for females is more than that of this vowel for males.

Finally, it should be noted that the vowel space has been studied in different languages, for instance, the studies of Barney and Peterson (1952), and Hillenbrand et al. (1995) on English vowels, Klein's study (1970) on Dutch vowels, the survey of Johngman et al. (1989) on modern Greek and German vowels, and the article of Most et al. (2000) on Hebrew Vowels. There are also some papers on Persian vowel space, such as Gharaati (2010), Mohammadi et al. (2011), Bijankhan (2013), Modarresi Ghavami (2013), Esfandiari and Alinezhad (2015), and Alinezhad (2016).

Keywords: Vowel space, Oral vowels, Nasalized vowels, Persian